Influence of canopy on precipitation and its nutrient elements in broad-leaved/Korean pine forest on the northern slope of Changbai Mountain

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Abstract: The precipitation distribution quantity of canopy in broadleaved/Korean pine forest was measured during the growing season (Jun.-Sept.) in 2001 in the Changbai Mountain, Jilin Province, P. R. China. Results indicated that the amounts of stem-flow, throughfall, and interception were 37.39, 322.12 and 109.69 mm, accounting for 7.97%, 68.65% and 23.38% of the total rainfall, respectively. The rate of stemflow was higher in Jul. and Aug. than other months. The rate of throughfall dropped off from Jun. to Sept., however, rate of interception changed contrarily from 19.43% to 31.02% during the growing season. According to our analysis, the concentration of nutrient elements were arranged as Ca> Mg> N> K> Fe > P> Cu > Mn for rainfall, K>N>Mg>Ca>P>Fe>Mn>Cu for throughfall, and Mn> P>K>Cu>Fe>N>Mg>Ca for being leached through canopy. Nutrients concentration in stewflow and throughfall changed significantly when rainfall passed canopy, and concentration of all elements increased except for Ca and Mg.
Keywords: Broadleaved/Korean pine forest; Precipitation distribution; Concentration; Nutrient elements; Canopy; Stemflow; Throughfall; Interception
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Introduction

Forest hydrology function is one important part of forest ecosystem. Studies on forest hydrology especially and energy flow and nutrient cycle will help our understanding in the functions of forest ecosystem. Forest canopy is the first interface factor when precipitation goes into forest, and directly influences the process of water cycle. It has important hydrological ecology significance (Wan *et al.* 2000). It's necessary to study influence of canopy on precipitation in broadleaved/Korean pine forest that is typical vegetation on the northern slope of Changbai Mountain. Although hydrological characters and water balance of forest ecosystem of the broadleaved/Korean pine forest on northern slope of the Changbai Mountain have been studied (Fan *et al.* 1992; Pei *et al.* 1995), they only studied in few facets. In order to provide some basic data for study on biogeochemical cycle, during the growing season in 2001, we described quantificationally influence of canopy on precipitation distribution quantity and nutrient elements, and expatiated on some ecology functions and hydrology benefit on broadleaved/Korean pine forest ecosystem.

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Site

Experimental area was located in Forest Ecosystem Station in Changbai Mountain (42°42′N, 128°06′E) at the elevation 740 m. The area of selected quadrat was 40 m×40 m. Affected by the monsoon, the climate of the region is present as the features a temperate continental mountainous climate with a cold weather during the long winter and short cool summer. The mean annual temperature ranges from 0.9 °C to 3.9 °C and annual precipitation is 632.8-782.4 mm. Precipitation is unevenly distributed in a year, about 71% of annual precipitation occurs from June to September. Annual solar radiation is 509.78-515.73 $kJ \cdot cm^{-2} \cdot a^{-1}$. The soil of the experimental area is dark brawn soil, the pH value of which is 5.3-5.6 (the depth 0-5 cm, soaked), (Cheng *et al.* 1992).

The dominant height of canopy layer is about 21.5 m and mean coverage 0.8. In experiment areas, main arbor species, number and the mean diameter at breast height are as follows: *Tilia amurensis* are 16 trees and mean DBH is 30.1 cm, *Fraxinus mandshurica* are 13 trees and mean DBH is 39.7 cm, *Quercus mongolica* are 2 trees and mean is DBH 53.8 cm. Average height of subcanopy layer is about 11.0 m, and main *Pinus koraiensis* are 25 trees and DBH is 35.1cm, *Acer pseudo-sieboldianum* are 12 trees and DBH is 11.8 cm, *Acer mono* are 11 trees and DBH is 17.8 cm. Shrub layer consists of 17 species, dominated by *Deutzia amurensis*, *Phildelphus schrenkii*, *Evonymus alatus*, *Corylus heterophylla*, *Acanthopanax senticosus*, *Viburnum burejaeticum*, etc.. Herbage layer contains 37 species, dominated by *Brachybotrys paridiformis*, *Carex*

pilosa, *Aegopodium alpestre*, *Meehania urticiforia*, etc..

Methods

Rainfall measurement

Samples were selected whenever stemflow and throughfall occurred during the growing season in 2001. Rainfall was observed and collected from a weather station, about 500 m away from study site.

Stemflow measurement

Stemflow was observed for selected 25 trees according to important value and class of DBH. The open plastic pipes were twisted two rings on the trunk at the height of 2 m above the ground level, and plastic containers were placed on the ground to collect the stemflow.

Throughfall measurement

Four V-shaped collecting slots of 4 m (length) × 0.2 m (width), and with bottom open at the end of the slot were placed at random in the study site. So we collected the throughfall by 200 L-containers from the open.

Nutrient elements analysis

Total N was measured by kjeldahl method, and P, Ca, Mg, Fe, Cu and Mn were measured by Inductively Coupled Plasma Emission Spectrometry (ICP-AES) method (Yu *et al.* 2001).

Results and discussion

Distribution of rainfall by canopy

According to our analysis, the amounts of stemflow, throughfall, and interception were 37.39, 322.12 and 109.69 mm, accounting for 7.97%, 68.65% and 23.38% of the total rainfall during the growing season. The probability ranges of rates of throughfall, stemflow, and interception are 0%-75.07%, 0%-10.78%, and 14.14%-100%, respectively, in individual rainfall process. From Table 1, the rates of the throughfall, stemflow, and interception had obviously augmented with increment of rainfall, but rate of interception declined from 100% to 17.69%. The stemflow hardly occurred when rainfall was less than 3 mm.

Table 1. Distribution of individual rainfall under different ranges

Rainfal range /mm	Time /h	Rainfall /mm	Stemflow /mm	Stemflow (%)	Throughfall /mm	Throughfall (%)	Interception /mm	Interception (%)
0.1-0.4	11	0.23	0	0	0	0	0.23	100.00
0.5-1.0	7	0.90	0	0	0.18	20.00	0.72	80.00
1.1-3.0	6	2.23	0.04	1.79	0.96	43.05	1.23	55.16
3.1-10.0	13	6.33	0.41	6.48	4.10	64.77	1.82	28.75
10.1-20.0	8	14.26	1.15	8.06	9.70	68.03	3.41	23.91
20.1-30.0	4	27.33	2.43	8.90	20.20	73.98	4.70	17.22
>30.1	2	70.65	6.45	9.13	51.70	71.38	12.50	17.69

As showed in Table 1, rainfall characters affected precipitation distribution, at the same time, canopy characters influenced the distribution of rainfall obviously, especially moisture capacity of canopy (Table 2). From Table 2, the results showed that throughfall and stemflow were positive correlated to rainfall intensity and moisture capacity of canopy, while interception changed contrarily.

Table 2. Influence of rainfall intensify and moisture capacity of canopy on rainfall distribution

Date	Rainfall /mm	i_m /mm·h^{-1}	J /mm h^{-1}	T /h	P_{i1} /mm	P_{5d} /mm	Throughfall /mm	Throughfall (%)	Stemflow /mm	Stemflow (%)	Interception /mm	Interception (%)
June 23	24.5	7.40	2.10	69	1.20	5.00	16.42	67.02	1.00	4.12	7.90	32.51
July 22	25.3	10.80	3.70	18	6.25	6.25	17.80	70.36	2.20	8.70	5.30	20.94
July 23	27.8	8.80	4.60	9	25.30	31.55	20.87	75.07	3.00	10.78	3.91	14.14
Aug. 1	20.8	6.00	1.00	52	0.10	35.60	14.80	70.81	1.68	8.04	4.42	21.15
Aug. 7	19.4	5.30	1.30	12	2.57	31.88	17.30	70.61	2.58	10.53	4.62	18.86
Sept.11	19.4	10.00	1.80	131	8.80	0.00	12.30	62.76	0.60	3.06	6.70	34.18

Notes: i_m--- Max. intensity of rainfall; J---average intensity of rainfall; T---Interval between two rain time; $P_{i\text{-}1}$---Rainfall at last time; P_{5d} ---Rainfall in per five-day.

Regulation of monthly precipitation distribution by canopy

Leaf-area index and leaf surface humidity were major factors that affected distribution of precipitation. Fig. 1 reflected the rates of stemfall, throughfall and interception of canopy in different months in broadleaved/Korean pine forest. The results indicated that the rate of stemflow was higher in Jul. and Aug. than other months, and rate of throughfall dropped off from Jun. to Sept., however, the rate

of interception changed contrarily to rate of throughfall. In June, trees leaves not only grew incompletely, but also the precipitation was lesser. Thereby, rate of throughfall was higher and rate of stemflow and interception were less. In July and August, which are rainy season and forest growing season, rate of throughfall dropped because leaves were more and bushy, interception increased, and the rates of stemflow was higher than that in other months. A dry season in a year was in September. Being rainfall lacked and leaf dry in this month, which leaded leaf absorption capability was more powerful, and then rate of interception increased but rate of throughfall decreased. The dynamic regularity of monthly distribution of rainfall in broadleaved/ Korean pine forest is in accord with that of other forestry types in temperate zone (Liu *et al.* 1996).

Nutrient content in precipitation by canopy

Rainfall is one of major nutrient resources that input into forest ecosystem. In the study area, we collected samples from rainfall, throughfall and stemflow 33 times in all, which based on stemflow and throughfall occurring (Rainfall range from 2.8 mm to 75.9 mm). The nutrient element concentration of rainfall changed clearly due to interception absorption and leaching by canopy. According to our analysis, the concentrations of nutrient element were arranged as Ca> Mg> N> K> Fe > P> Cu > Mn for rainfall, K>N>Mg>Ca>P>Fe>Mn>Cu for throughfall, and Mn> P>K>Cu>Fe>N>Mg>Ca for being leached by canopy (Table 3). Nutrient elements in stemflow and throughfall changed significantly when rainfall passed canopy, and all for element concentration increased except for Ca and Mg.

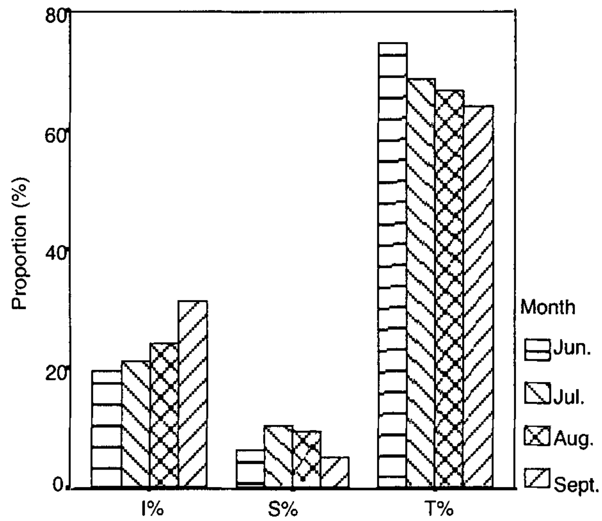

Fig.1 Rate of stemfall, throughfall and interception of canopy in different months

T%--- Rate of throughfall; I%--- Rate of interception; S%--- Rate of stemflow

Table 3. Concentration of elements in rainfall changed by canopy influence (mg·L^{-1})

Element	Concentration of elements				
	Rainfall	Throughfall	Stemflow	Leaching by canopy B+C-A	Leaching index B/A
N	1.362	1.853	2.915	3.046	1.036
P	0.030	0.138	0.596	0.704	4.600
K	1.250	5.573	7.240	11.563	4.458
Ca	6.146	0.893	1.162	-4.091	0.145
Mg	1.445	0.992	1.306	0.853	0.682
Fe	0.042	0.072	0.169	0.196	0.682
Cu	0.002	0.004	0.006	0.008	1.600
Mn	0.013	0.072	0.130	0.189	2.000
pH	7.11	7.17	7.04		5.538

Notes: A---(Concentration of elements in rainfall); B---(Concentration of elements in throughfall); C---(Concentration of elements in stemfall).

Nutrient elements in rainfall came from gas ingredients and dust substances, and concentration was affected by many factors, e.g. geographic environment, season and degree of air pollution (Zhang *et al.* 1992). There were significant differences between concentrations of nutrient elements in rainfall and throughfall in different months (Table 4 and Table 5). Those differences were mostly affected by precipitation, and nutrients concentration was diluted. Nutrient concentrations decreased with increment of precipitation.

Although concentrations for Ca and Mg in throughfall were lower than that in rainfall (Table 4 and Table 5), Ca and Mg deposited in the old leaf more than that in the tender leaf, due to being hardly leached and then cumulated in leaf tissues. However, K, P and Fe were leached easily due to positive move, and they pooled in bud and tender leaf. Cu and Mn were trace elements with positive move and were also leached easily (Feng *et al.* 1985; Li *et al.* 1994). The concentrations of Ca and K in stemflow of spruce were higher than that of broadleaved/Korean pine.

The concentration of elements in stemflow changed consistently with that in throughfall. The phenomenon existed in natural secondly forest and virgin Korean pine forest in temperate zone as well (Liu *et al.* 1996), but it didn't appear in artificial larch forest, pine forest and pine-spruce-fir forest (Liu *et al.* 1996; Huang *et al.* 2000; Cheng *et al.* 1993). Concentration of elements in throughfall changed more distinctly in broadleaved/Korean pine

forest than in tropic forest and sub-tropic forest (Ma 1989; Tang *et al.* 1992). This phenomenon may be caused by tree species, and affected by many complex factors. Other reasons should be demonstrated by further experiments in the future.

Table 4. Concentrations for nutrient elements in rainfall in different months ($mg \cdot L^{-1}$)

Month	Rainfall /mm	N	P	K	Ca	Mg	Fe	Cu	Mn
June	91.30	1.767	0.030	0.896	9.390	1.935	0.043	0.004	0.031
July	229.60	0.568	0.019	2.167	4.098	0.624	0.037	0.000	0.001
August	107.20	1.386	0.019	1.462	0.510	1.545	0.034	0.001	0.001
September	41.00	1.727	0.052	0.475	10.586	1.668	0.054	0.003	0.019

Table 5. Concentration for nutrient elements in throughfall in different months ($mg \cdot L^{-1}$)

Month	Rainfall/ mm	N	P	K	Ca	Mg	Fe	Cu	Mn
June	91.30	1.557	0.057	0.927	0.509	0.270	0.064	0.011	0.071
July	229.60	1.770	0.118	3.997	0.543	0.759	0.089	0	0.033
August	107.20	1.710	0.063	2.583	1.524	0.479	0.078	0.001	0.012
September	41.00	2.375	0.314	14.785	0.996	2.460	0.057	0.004	0.172

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